The antarctic meteorites Yamato-82192 and Yamato-82193 were recognized to originate from impact ejection from the Moon [cf. 1, 2]. The objective of this study is to derive the cosmic-ray exposure history on the lunar surface and in space and to calculate the terrestrial age of these meteorites. A sample of about 0.3 g of each meteorite was allocated for the measurement of the noble gas isotopic abundances. In this paper I present the results obtained for the cosmic-ray produced component in >25 μm grain size fractions. The relevant data are given in Table 1.

Average shielding during cosmic-ray exposure. In order to calculate cosmic-ray exposure ages from the amounts of cosmogenic nuclei, the respective production rates have to be known. Since production rates are depth dependent, the shielding depths of the samples were derived. The depth sensitive cosmogenic ratios $^{22}\text{Ne}/^{21}\text{Ne}$ and $^{131}\text{Xe}/^{126}\text{Xe}$ both indicate a shallow shielding. The theoretical depth profile of the $^{131}\text{Xe}/^{126}\text{Xe}$ ratio was calculated for the chemical abundances of the investigated meteorites [3, 4, 5] using the data given by Hohenberg et al. [6]. The measured ($^{131}\text{Xe}/^{126}\text{Xe}$) ratios correspond to a shielding <25 g/cm². Average shielding depths during cosmic-ray exposure of 17 g/cm² for Y-82192, 82 and of 10 g/cm² for Y-82193, 100 are adopted.

The noble gas production rates were calculated for the adopted shielding, inserting the abundances of the target elements [3, 4, and 5]. The following methods were employed: $^{21}\text{Ne}$ - Hohenberg et al. [6] and Schultz and Freundel [7]; $^{38}\text{Ar}$ - Hohenberg et al. [6] and Freundel et al. [8]; $^{81}\text{Kr}$ - Regnier et al. [9] and Marti et al. [10]; $^{126}\text{Xe}$ - Hohenberg et al. [6] and Marti et al. [10]. For each species the average value obtained from the two methods was adopted. For the 4π geometry conversion a factor of 2 was used.

Galactic cosmic-ray exposure ages were calculated, on the one hand, using $^{81}\text{Kr}$-Kr dating: $T_{\text{81}} = \frac{\tau_{81}}{\tau_{83}} \left( \frac{p_{81}}{p_{83}} \right) \left( \frac{83\text{Kr}}{81\text{Kr}} \right)_c$ with $\tau_{81} = 303000$ y; $p_{81}/p_{83}$ is the production rate ratio [11].

On the other hand, exposure ages based on the stable nuclei were derived for a 4π- and a 2π-exposure geometry. Table 2 shows that the exposure ages based on stable isotopes agree within experimental errors. For Y-82192 Takeoka [12] and Weber et al. [13] both obtained a 4π-exposure age of about 10 m.y. for a shielding of <40 and 10 g/cm², respectively.

Pairing. The data in Tables 1 and 2 confirm beyond any doubt that the two meteorites represent different splits of the same meteoroid as suggested by several authors [1, 3, 14].

Terrestrial age. $^{10}\text{Be}$ data given by Nishiizumi et al. [14] show that Y-82192 and Y-82193 experienced a 4π exposure for at least about 5 m.y. of their most recent cosmic-ray exposure history. Therefore, $^{81}\text{Kr}$ was present at the time of fall in equilibrium activity and the terrestrial ages can be calculated from $T_{\text{terr}} = \frac{\tau_{81}}{\tau_{83}} [\frac{\tau_{81}^{\text{stable}}}{\tau_{81}^{\text{stable}}}]$. The resulting terrestrial ages are 70'000 y and 80'000 y, respectively; they are consistent with Nishiizumi et al.'s estimate of <10⁵ y and are typical for meteorites collected in the Yamato mountains [15].

Table 1. Cosmic-ray produced noble gases

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{\text{3}}\text{He}$</th>
<th>$^{\text{21}}\text{Ne}$</th>
<th>$^{\text{38}}\text{Ar}$</th>
<th>$^{\text{83}}\text{Kr}$</th>
<th>$^{\text{126}}\text{Xe}$</th>
<th>$^{\text{22}}\text{Ne}$</th>
<th>$^{\text{131}}\text{Xe}$</th>
<th>$^{\text{81}}\text{Kr}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-82192,82</td>
<td>8.1±1.0</td>
<td>2.14±0.10</td>
<td>2.31±0.15</td>
<td>11.8±2.5</td>
<td>0.49±0.05</td>
<td>1.25±0.05</td>
<td>3.43±0.30</td>
<td>75.8±8.0</td>
</tr>
<tr>
<td>Y-82193,100</td>
<td>7.2±1.0</td>
<td>2.18±0.10</td>
<td>2.81±0.20</td>
<td>11.9±2.5</td>
<td>0.50±0.10</td>
<td>1.28±0.05</td>
<td>2.74±0.60</td>
<td>71.4±4.0</td>
</tr>
</tbody>
</table>

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COSMIC-RAY EXPOSURE HISTORY OF Y-82192 and Y-82193

Eugster, O.

Table 2. Galactic cosmic-ray exposure ages (10^6 years) and terrestrial ages

<table>
<thead>
<tr>
<th>Sample</th>
<th>Apparent 81Kr-Kr age (10^6 years)</th>
<th>T21</th>
<th>T38</th>
<th>T83</th>
<th>T126 (av(stable))</th>
<th>T126 (av(stable))</th>
<th>Tterr</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y-82192,82</td>
<td>13.9</td>
<td>10.2</td>
<td>12.3</td>
<td>9.0</td>
<td>11.4</td>
<td>10.7</td>
<td>21.4</td>
</tr>
<tr>
<td></td>
<td>±1.5</td>
<td>±2.0</td>
<td>±2.5</td>
<td>±3.0</td>
<td>±2.5</td>
<td>±1.3</td>
<td>±2.6</td>
</tr>
<tr>
<td>Y-82193,100</td>
<td>13.9</td>
<td>10.5</td>
<td>13.8</td>
<td>9.0</td>
<td>11.2</td>
<td>11.1</td>
<td>22.2</td>
</tr>
<tr>
<td></td>
<td>±1.0</td>
<td>±2.0</td>
<td>±2.5</td>
<td>±3.0</td>
<td>±2.5</td>
<td>±2.0</td>
<td>±4.0</td>
</tr>
</tbody>
</table>

History of Y-82192 and Y-82193. The most probable scenario for the history of the Y-82192/3 meteoroid can be summarized as follows: Excavation on the Moon from a depth completely shielded from cosmic rays occurred 11 m.y. ago. This impact event caused ejection from the Moon's gravitational field. The meteoroid was captured by the Earth about 70,000 y ago. Only if future analyses of the 53Mn activity show that this radioisotope with a half-life of 3.7 m.y. is not in equilibrium with respect to a 4m exposure, the above scenario has to be modified in the sense that a pre-exposure occurred on the lunar surface. In such a case two different impacts have to be invoked to excavate and propel the meteoritic material.

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References: